MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ENT3056 – ADVANCED FABRICATION TECHNOLOGY

(NE)

9 MARCH 2017
09:00 a.m. - 11:00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to APPENDIX at page 6 and 7 for a list of physical constants, a list of formulas, and the error function table.

QUESTION 1

(a) With clear descriptions, make comparison between the Czochralski (CZ) and Float Zone (FZ) crystal growth methods, in the contexts of *crucible contamination*, *crystal resistivity*, and *wafer diameter*, respectively.

[9 marks]

(b) Give **TWO (2)** purposes of the flat grinding in wafer processing steps.

[3 marks]

(c) An *n*-type silicon (Si) boule which is to be grown by using the Czochralski (CZ) method should contain antimony (Sb) with concentration of 10^{17} cm^{-3}. Given that the initial load of electronic-grade silicon (EGS) in the crucible is 100 kg, segregation coefficient of antimony is 0.023 and atomic weight of antimony is 121.76 a.m.u., determine the weight of the antimony that should be loaded in the crucible prior the melting process.

[6 marks]

(d) (i) List the **SIX (6)** typical growth steps in chemical vapor deposition (CVD).

[3 marks]

(ii) Explain how the plasma-enhanced chemical vapor deposition (PECVD) differs from the conventional CVD associated with the substrate temperature, T_s.

[4 marks]

QUESTION 2

(a) By sketching the plots of *dopant concentration* versus *depth from the substrate surface*, discuss the profiles of the dopant distributions for *constant-source* and *limited-source* diffusions, respectively.

[3+6 marks]

(b) (i) **Figure Q2(b)** shows the projected range and straggle for various types of dopants in silicon (Si). Given that an *n*-type Si wafer with background concentration of 10^{16} cm^{-3} is implanted with boron (B) ions at 100 keV with a dose of 1.9×10^{11} cm^{-2}, determine the junction depths of the *p-n* junction that have been created.

[6 marks]

(ii) Suggest **ONE (1)** parameter that can be controlled on the ion implantation system in order to alter the *projected range* and the *dose* of the ions, respectively.

[2 marks]

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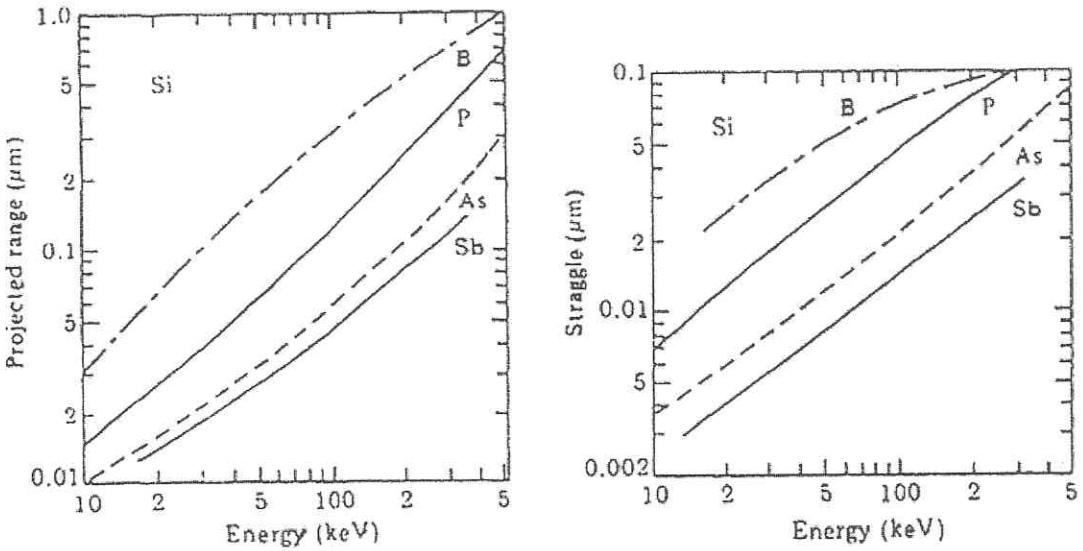

Figure Q2(b)
(Courtesy of E. Remini, 1995)

(c) (i) Explain briefly the reactions happened on positive photoresist (+PR) and negative photoresist (–PR), respectively, when exposed with ultraviolet (UV) light and washed using developer solution.

[3 marks]

(ii) **Figure Q2(c)(ii)** shows the final patterned structure originate from the structure as shown in **Figure Q2(c)(i)**. Construct the photomasks that had been used for the photolithography processes utilizing –PR in order to obtain the final patterned structure. Clearly label the transparent and opaque portions of the masks.

[3 marks]

(iii) Suggest **ONE (1)** material that made up the transparent and opaque portions of the masks, respectively.

[2 marks]

Figure Q2(c)(i)

Figure Q2(c)(i)

Continued...

QUESTION 3

(a) Discuss the main limitation for each of the advanced lithography technique as follows:

- Electron beam lithography
- Extreme Ultraviolet (EUV) lithography
- X-ray lithography

[9 marks]

(b) Evaluate the performance of wet etching and dry etching in the contexts of *etch selectivity* and *etch cleanliness*.

[6 marks]

(c) **Figure Q3(c)** shows the cross-sectional structure of a bottom-gate/top-contact (BG/TC) organic field-effect transistor (OFET) which constitutes of gate electrode, dielectric layer, organic semiconducting layer, two source/drain (S/D) contacts, and a passivation layer, grown on a substrate. By sketching the cross-sectional structure upon each of the process step, design the fabrication processes in order to achieve this device. Label the structures, state the processes, and indicate both the mask patterns and type of resist clearly.

[10 marks]

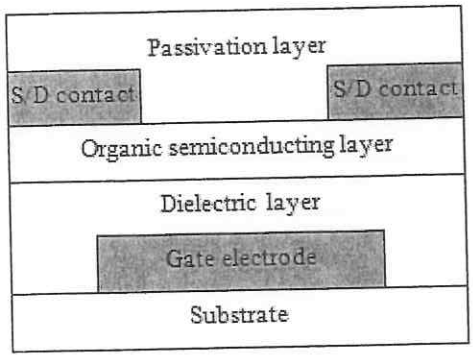

Figure Q3(c)

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QUESTION 4

(a) Give **THREE (3)** basic requirements for the interconnect which is used in the integrated circuits (ICs) technology.

[3 marks]

(b) Analyse the performance of *aluminium* (Al) and *copper* (Cu) used for interconnections in the metallisation layers of integrated circuits (ICs), respectively.

[5 marks]

(c) (i) Discuss **TWO (2)** unwanted reactions that can take place during the sintering process of aluminium (Al) contact on silicon (Si), or other high temperature processes subsequent to the Al deposition in interconnect fabrications.

[6 marks]

(ii) Suggest **TWO (2)** solutions to eliminate the reactions mentioned in **(c)(i)**.

[2 marks]

(d) Describe the methods used to further lower the sheet resistance of diffusion and polysilicon interconnects in the integrated circuit (IC) technology.

[4 marks]

(e) Consider a 250 μm long polysilicon interconnect that has a thickness of 300 nm and resistivity of 1000 μΩ·cm and runs over an oxide layer that has a thickness of 600 nm and dielectric constant of 3.9. Determine the resistance-capacitance (R-C) time constant of the polysilicon interconnect. How would the result obtained affect the performance of the circuit?

[4+1 marks]

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APPENDIX

Physical Constants:

Avogadro number, $N_{avo} = 6.02217\times10^{23}$ mol^{-1}
Boltzmann constant, $k = 1.380622\times10^{-23}$ J K^{-1} = 8.61712×10^{-5} eV K^{-1}
Electronic charge, $e = 1.60219\times10^{-19}$ C
Electron rest mass, $m_o = 9.10956\times10^{-31}$ kg
Electron volt, 1 eV = 1.60219×10^{-19} J
Si yield strength = 2×10^{7} dynes cm = 7 GPa
Latent heat of fusion for Si, L = 340 cal g^{-1}
Thermal conductivity of Si, k = 0.21 W cm^{-1} °C^{-1}
Amount of heat of 1 calorie = 4.14 J
Density of bulk Si = 2.33 g cm^{-3}
Density of molten Si = 2.53 g cm^{-3}
Electric current of 1 A = 1 C s^{-1}
Atomic mass unit of 1 amu = 1.66053×10^{-27} kg
Magnetic flux density of 1 T = 1 Wb m^{-2} = 10^4 G
Angstrom unit of 1 Å = 1×10^{-10} m = 0.1 nm = 1×10^{-4} μm
Permittivity of free space = 8.85×10^{-14} F cm^{-1}
Pressure of 1 Torr = 133.32237 Pa

Formulas:

$\phi = \frac{P}{\sqrt{2\pi mkT}} = 2.64\times10^{20}\frac{P}{\sqrt{MT}}$	$N(x) = \frac{Q_o}{\sqrt{2\pi}\Delta R_p} e^{\left[-\frac{1}{2}\left(\frac{x-R_p}{\Delta R_p}\right)^2\right]}$
$\lambda = \frac{kT}{\sqrt{2}\,\pi P d^2}$	$N(x,y) = \frac{N(x)}{\sqrt{2\pi}\Delta R_\perp} e^{\left[-\frac{y^2}{2\Delta R_\perp{}^2}\right]}$
$R = \sqrt{\frac{m}{2\pi k\rho^2}}\frac{P}{\sqrt{T}}\frac{A}{4\pi r^2}$	$C_s = \frac{Q}{\sqrt{\pi Dt}}$
$RC = \frac{R\,L^2\,\varepsilon}{d}$	$Q = 2C_s\sqrt{\frac{Dt}{\pi}}$
$C(x,t) = C_s erfc\left[\frac{x}{2\sqrt{Dt}}\right]$	$Q = \sqrt{2\pi}N_p\Delta R_p$
$C(x) = \frac{Q}{\sqrt{\pi Dt}} e^{-\left(\frac{x}{2\sqrt{Dt}}\right)^2}$	

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Values of the error function $\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3494	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\operatorname{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi}\, t} \exp(-t^2)$

erfc (t) = 1 - erf (t)

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